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CLIMATE CHANGE ADAPTATION AND MITIGATION STRATEGIES: REFLECTIONS FROM SMALL LANDHOLDING FARMERS OF TAMILNADU

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ABSTRACT

The agricultural production process depends on the climate, whereas environmental challenges severely affect yield. Besides, the implication of adaptive strategies is the ultimate weapon for farmers to deal with vulnerability. Considering the economic importance of climate change, this paper attempts to identify the rationale behind the chosen adaptation technique and the factors influencing the chosen mitigation method. Furthermore, the study analyses the risk aversion behaviour among small and marginal farmers, along with the incidence of de-peasantization. A total of 480 marginal and small landholding farmers of the Madurai district were selected using a stratified random sampling technique and data were gathered through a well-structured interview schedule, from December 2021 to June 2022. The study employed a logistic regression model to ascertain the effects of the region with limited irrigation facilities and its adaptation behaviour, and a multinomial logistic regression model to predict the dichotomous placement of a dependent variable based on multiple independent variables. The results of the study revealed that the rationale for strategic choice reflects a wide range of factors, primarily farmers' satisfaction levels. Among the barriers, most farmers' efforts were hampered by economic barriers, followed by technical and institutional barriers. Also, two-thirds of farmers rely on semi-liquid assets and other jobs to manage risk. Besides, a maximum of one-third of the farmers lost 320 USD to 640.5 USD hectare^{-1} in a year. Instead, crop loss and food insecurity are the main reasons for de-peasantization. Moreover, the loss is higher than the investment made for the food production. Concerning risk, farmers have a three-tier risk association in terms of production, price and finances. These findings shed light on considerations that farmers must take into account, as climate change cannot be reversed without first addressing its ramifications. Therefore, the onus is on the Union government in general and the State government, in particular, to create understanding among the farmers about the need and necessity of the strategies. Therefore, organizing adaptation workshops and inclusive programs to enrich the knowledge of smallholder farmers is the need of the hour.

(Key words: Barriers, de-peasantization, investment, risk aversion, climate change)

INTRODUCTION

The term adaptation is defined as "adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in process, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change" (Anonymous, 2007). Nevertheless, socio-economic and income inequalities among farmers are also a major factor in the decline. The most vulnerable actors for changing climate are the small and marginal farmers (Panda and Singh, 2016). As they are poor and marginalized, their coping and risk management skills are limited towards the climate change and related hazards. Further, the ambiguous roles of public sector, information uncertainty between stakeholders and weedy administration systems are also a major threat to the adoption of adaptation strategies. Henceforth, there is a greater need for the greater involvement in the enactment of systematic policies related to climate change both: horizontally (among the agricultural and environmental authorities) and vertically (between province, area and community). While largely absent, what little evidence does exist is mostly anecdotal. Furthermore, climate change is more likely to move existing crises into a new dimension. India is among the countries most vulnerable to climate impacts (Thaker and Leiserowitz, 2014). As agriculture is directly related to climate, changes in climate can have a significant impact on crop growth (Roychoudhary *et al*., 2015). Thus, climate change and impacts significantly reduce agricultural production.

Awareness of climate change is medium to low

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among farmers in Tamil Nadu. Additionally, it is noteworthy that more agricultural communities predicted only uneven rainfall. Besides, awareness about acid rain, wind speed variability, and heat and cold waves is very low (Sangeetha *et al*., 2021). There was a heightened necessity for the small landholding farmers to be aware of costs and nature of climate change impacts. Farmers' risk perceptions on the impact of climate change in agriculture are determined to strengthen their commitment to adaptation and mitigation strategies (Raghuvanshi and Ansari, 2016). In this line, farmers are the first to be affected by climate change and adaptation are the ultimate weapon for them to reduce the impact (Soubry *et al*., 2020). The diversion of farmers from farm occupation tends to afford little income, whereas the one sought that perception of efficacy on changing Climate resulted on change of time over plantation and harvest, and the farmers' experience more than a decade perceived more familiarity on the adaptation measures (Shi *et al*., 2019). Comparably, in the western zone of Tamil Nadu the farmer's education level, size of household, gender and, age or experience played a vital role in the selection of adaptation strategies of technology to cope with the changing climate. Moreover, with the size of farmland, on the fine major crops, the adopters achieved higher efficiency of output as compared to the non- adopter's category, except maize (Vijayasarathy and Ashok, 2015).

Correspondingly, the agricultural system responds to the changing environment through adaptive strategies (Raghuvanshi and Ansari, 2016). Although there are studies on awareness and adoption, they have not focused much on regional adaptation strategies. Also, little attention is paid to the rain-fed agriculture, cost to farmers and the risk factors associated with climate change. Further, there is a need to focus on resource-poor farmers (small and marginal farmers) because their resilience to climate change impacts would be particularly weak (Thulasiram and Sivaraj, 2020).

On the contrary, a study conducted in Maharashtra recommended Integrated Farming System (IFS) to improve livelihood security, employment and income generation of rural farmers. Precisely, the study asserts that the inclusion of various components such as crops, livestock, border garden and kitchen garden should be a source of income, resource sustainability and climate mitigation beyond off-farm work (Saoji *et al.,* 2020). According to a study carried out in Punjab, guar-wheat and cotton-wheat cropping sequences were more productively efficient than the other cropping sequences. The research also confirmed that the cotton-wheat and guar-wheat cropping sequences had preserved soil health by increasing the amount of organic carbon, nitrogen, phosphorus, and potassium in the surface soil (Kaur *et al*., 2017). Besides, the rapid phase of adoption behaviour depends upon the level of risk associated with the loss of income (Alpizar *et al.,* 2012). Therefore, to achieve sustainability, there is a pressing need to create a constructive and comprehensive knowledge base for decision-making by categorising and integrating the diverse information on farmers' adaptative actions (Dattaa *et al*., 2022). In this context, this paper attempts to find out i) the rationale behind the chosen strategy and the factors influencing the chosen method, ii) cost, risk aversion and income losses experienced to mitigate the impact and iii) to identify the incidence of de-peasantization activity. Moreover, the study seeks to find the answers for the following questions i) Are the impacts of different land-based adaptation and mitigation strategies regional? and ii) what factors influence farmers' decision to adopt adaptation measures?

MATERIALS AND METHODS

Research design

The present study was a qualitative-cum-quantitative work which incorporates a multistage sampling method for the selection of sample respondents from the total population. In this line, Madurai was the only region that receive the highest mean temperature of 42^{o}C between the month of March and September. Madurai district has seven taluka as and thirteen blocks out of which Usilampatti taluk (riverbed) with highest irrigated area (8,140 ha.) and Thirumangalam taluk (rainfed) with least irrigated area (2,649.7 ha.) have been selected (Block "G" Return, 2020). In the second stage, the researcher used stratified random sampling technique to draw specific sample populations. A total of 480 farming households, in particular, 153 from Veppanuthu, 132 from Ayyanarkulam, 99 from Villur and 96 from S.P. Natham have been chosen for the analysis. In addition, the study gathered information about adaptation and mitigation strategies, structural barriers, risk coping mechanisms, incidence of de-peasantization activity from the farming households.

Data collection

The study had designed and used a well-structured interview schedule for the collection of data. Farmers those continue to farm on less than or equal to 2 hectares (small farmers - d" 2 hectares and marginal farmers - d" 1 hectare) of land have been selected as the respondents of this study. Besides, the investigation was conducted on those in the field belonging to 480 selected households. Data were collected from this category of farmers under various themes such as household rosters, implication of adaptation and mitigation strategies, and the incidence of de-peasantization activities. Besides, the study was carried out between December 2021 and June 2022 respectively. Finally, the collected qualitative data were coded and converted into quantitative form for further analysis.

Tools and techniques

The study attempts to solve the problem following a two-step process. In the preliminary stage the study attempts to find out the factors which were more compatible with land with less irrigation facility using binary logistic regression model. In the second step, the study employed multinomial logistic regression model to identify the region-specific adaptive behaviour of the farmers' over changing climate.

Abend (2008) stated that the need to develop a theoretical framework was to explain and describe "why a research problem appears". This study adopted the Theory of Planned Behaviour (TPB) to assess the farmers approach towards strategy. The TPB have three main components: attitude, subjective norms, and behavioural control which shape a person belief to behavioural intentions (Ajzen, 1985).

When the dependent variable was categorical and continuous in nature then preference of logistic regression model was most appropriate (Saini, 2021). For the past two decades logistic regression modelling have been frequently used as a prediction tool (Verhagen 2007). Thus, the study used logistic regression model to ascertain the effects of region with limited irrigation facility and its adaptation behaviour. The logit is the natural logarithm (ln) of odds of Y, and odds are ratios of probabilities (p_i) of Y happening to probabilities (1" p_i) of Y not happening. Therefore, the binary logistic model is specified as:

$$logit\ (Y) = \ln\left({}^{p_i}/_{1 - p_i}\right)$$

In the above equation the dummy variables were assigned as [1 = yes; 0 = otherwise] '1' has been assigned instead of 'yes': if the small and marginal farmers belong to the area lacking irrigation facilities and '0' otherwise.

In this research to predict the dichotomous placement on a dependent variable based on multiple independent variables a multinomial logistic regression model was used. The model is specified as,

$$Prob\ (Yi = j) = \frac{e^{\beta_i X_i}}{\sum_{k=0}^{4} e^{\beta_k X_i}},\ j = 1, 2, 3, 4$$

In the following equation 'j' (1 – Veppanuthu, 2 – Ayyanarkulam, 3 – Villur, 4 – S.P. Natham) represent the respective select village panchayats of the study region.

RESULTS AND DISCUSSION

In the study area, 80.6 per cent and 19.4 per cent of small landholding farmers were aware and unaware of climate change. Similarly, 80.6 per cent and 19.4 per cent perceived long-term change in climate factors and perceived no change, respectively. In terms of rainfall and temperature trend, 43.8 per cent witnessed a decrease in rainfall, 30.6 per cent experienced an increasing trend in temperature, and the remaining 25.6 per cent observed a fall in rainfall and an increase in temperature patterns. Among prevailing problems, 26.0 per cent and 21.0 per cent of farmers came across decreasing trend in crop yield and unprofitable crops due to climate change. Of the total, 25.8 per cent believed that climate change was responsible for increasing drought in the study area, and 21.0 per cent believed that climate change was responsible for reduced crop growth. As a source of knowledge about climate, maximum 35.2 per cent of farmers were resourced through gram panchayat and 29.0 per cent through lead farmers.

Choice and rationality of adaptation strategies

The data regarding choice and rationality of adaptation and mitigation strategies were shown in Table1. Of the total, the majority 88.1 per cent of small and marginal farmers do not face any kind of external pressure from their fellow farmers, while 11.9 per cent were advised to practice conventional farming for profit maximisation. At most, the irrigation enriched region farmers were already following conventional type farming. Thus, the level of external pressure was much lesser than the expectation level. Because of the fragmented land issues the change-over from traditional to conventional was easier for the small and marginal.

In terms of mitigation strategies, a quarter 20.8 per cent of the farmers prefer increasing pesticides, changing crop varieties, shifting jobs and practising crop rotation. Besides, 18.3 per cent changed the harvest time and adopt crop diversification methods. On the other hand, 11.9 per cent and 11.3 per cent of farmers, respectively, chosen agroforestry, salinity tolerant crops, soil protection techniques and living fences, multipurpose trees, and zero tillage methods. Similarly, 9.5 per cent each wished to increase alternative income, irrigation, mulching and applying soil protection technology to tackle the impacts of changing climate. In addition, 8.3 per cent of the farmers mitigated the climate through the integrated farming system and changing the planting time, while 7.1 per cent wished to take crop insurance and shed their focus on the weather forecast. Moreover, the remaining 3.3 per cent used drought-tolerant crops, change in planting structure and cover crop systems to combat extreme weather events. In terms of strategy, leasing the land and migrating to off-farm jobs was highly preferred by the marginal farmers. In the field of research, conversely, farmers changed sowing, ploughing, weeding and so on not because of the unpredictable weather but because of labour shortages.

In terms of rationality, it was found that 19.2 per cent of the farmers were based on the effectiveness of the selected strategies, while 17.9 per cent of the farmers depended on the extent of the arable land they hold. Besides, 16.0 per cent, 13.5 per cent and 10.0 per cent of farmers' rationalization depended on the size of livestock/sheep herd and climatic information. Following that, 8.8 per cent, 8.3 per cent, 4 per cent and 2.3 per cent of farmers' choices were based on extension communication, farm and out-of-farm income, access to credit and education level, respectively. Despite the strategies effectiveness, mostly the choice of strategies depended on the weather condition, size of holding and credit availability.

Prior to adoption, it was notable that the yield for 100 per cent farmers was less than 25 bags hectare^{-1}, while the production rate of 98.8 per cent of farmers faced a positive change from 25 to 30 bags hectare^{-1} during the post-adaptation process. In terms of satisfaction, 37.5 per cent of farmers have reported that the adaptive strategies met their standards and 33.5 per cent of the farmers reported that the strategies were substandard. Furthermore, 21.9 per cent and 7.1 per cent of farmers reported that the strategies were far below and too high for their respective standards. Even though the production came across with a slight deviation, one-third of the farmers were upset with the adoption, while the other one-third was satisfied. Meanwhile both the groups belong to the irrigation facilitated regions (Veppanuthu and Ayyanarkulam). Notably, the small and marginal farmers surpass social pressure and credit accessibility problems at once. Nevertheless, the peasants belong to the same region, religion and caste, the power and capital; the twin brothers played the decidual role.

Structural barriers

As the solution come up with the problem, farmers too face difficulties while implementing adaptation strategies. In Table 2, data regarding the structural barriers faced by the farming households have been presented. An overwhelming majority 57.1 per cent of farmers' efforts were hampered by economic conditions, followed by technology (27.1 per cent) and institutional barriers (15.8 per cent). Economically, 41.04 per cent were affected due to high adaptation cost, lack of financial facilities and expensive inputs, whereas the remaining 16.04 per cent were affected because of lacking storage facilities and retention of small and fragmented land. Due to technical constraints, 16.3 per cent of farmers were severely affected by the lack of drought tolerant crop varieties, 4.8 per cent by the lack of local machinery, 1.9 per cent reported regarding the lack of research on climate change and adaptation to different agricultural dimensions and 4.2 per cent by less irrigation and water capacity infrastructure developed in rainfed areas. Institutionally 3.5 per cent, 2.7 per cent and 9.6 per cent of farmers were affected respectively by problems such as poor coordination and disability, unequal distribution of responsibility for adaptation and inadequate focuses on their transformation.

The main reason for the economic waning of small and marginal was due to the inverse relationship existing between the input prices and the prices of produced goods. In particular, rising input prices and falling paddy prices reduced the ability of a farmer to move further into the production process, reinforcing de-peasantization. In addition, as there were very few short duration profitable crop varieties in the market the Akshaya paddy variety introduced in Kerala was widely used by the farmers in the study area for cultivation. The idea of the farmers was that 'two dairy cows were enough to buy groceries for two months and two hectares of white maize was enough for one month of rice consumption'. Hence, adopting the most expensive inputs and adopting the most expensive adaptation techniques was not so easy for subsistence agriculture. Nevertheless, farmers said that 'to know the interest of government officials, the quality of the fertilizers provided and the suffering of the farmers during procurement of the grown crops' was sufficient.

Risks and risk coping mechanisms in farming

Risk associated in farming

Table 3 highlights the risk and risk coping mechanisms followed by the farmers. Concerning risk, farmers have a three-tier risk association in terms of production, price and finances (37.3 per cent). Individually, a major risk faced by farmers was the risk associated with the production process (16.9 per cent) followed by institutional (13.5 per cent) and price or market risk (10.2 per cent). Besides, 9.8 per cent, 8.3 per cent and the remaining 4.0 per cent of farmers faced financial, human/personal and uncertain natural growth processes of crops and livestock respectively.

Risk coping mechanisms

Among the ways to deal with risk, 28.1 per cent of farmers owned semi-liquid assets, work outside the farm and economic activity which was not related to agriculture. Besides, 25.0 per cent used precautionary savings, credit balance and liquid cash accumulation strategies, while 21.5 per cent took up crop insurance, financial reserve maintenance and animal insurance. In addition, 20.8 per cent were trained to farm diversification, adopt land lease agreements and evade debt, whereas the remaining 4.6 per cent of farmers preferred to join a producer team and collaborate with the supplier and receiver of both the by-product and the produce goods.

Loss of income and time

With respect to the loss of annual income hectare^{-1}, a maximum of 30.6 per cent of farmers had lost 320 USD to 640.5 USD, whereas 29.8 per cent of the farmers cost ranged between 160 USD and 240 USD. Moreover, 21.7 per cent, 12.3 per cent and 5.6 per cent of farmers lost 240 USD to 320 USD, over 640.5 USD and between 95.8 USD and 160 USD due to climate variability. As to loss of time, the majority 68.1 per cent, 26.0 per cent and 5.8 per cent of farmers lost less than 6 months, from 6 to 12 months and between 1 and 2 years for mitigation purposes.

A 60 per cent price increase in inputs such as fertilizers, feedstuffs and plant protection products in food production stimulates the production risk thereby triggering the financial crisis among the small and marginal farmers. The farmers also reported that 'if the input prices have a linear increasing trend, then the farming would face huge exit of farmers from farming'. The production cost for paddy ranged from 303.7 USD to 315.8 USD, whereas the production had walloped by the heavy rains that occurred in the year 2020. Moreover, the loss was higher than the investment made for the food production. Ezung *et al*.(2020) suggested farmers should practice vermicomposting in green crop which supports soil stability to increase gram yield, higher profitability and reduce losses. Similarly, a trade-off was occurring when adaptive strategies were adopted. The land could not be used for production purposes. Therefore, the farmers would be forced to look for another job for at least 6 months.

The incidence of de-peasantization activity

Regarding de-peasantization (Table 4), 93.5 per cent of the total farmers migrated for subsistence. Also, agricultural wage works, painting, electrical works, motor lifting and drivers were the only jobs availed to semi- or unskilled farmers when they migrate. In particular, 31.3 per cent were displaced due to crop failure, 20.6 per cent due to food insecurity and 17.5 per cent due to unemployment. Moreover, 12.5 per cent, 8.1 per cent and 3.5 per cent of farmers were displaced because of rural poverty, social insecurity and drought, respectively. Despite migration, farmers were more accustomed to short-term migration (91.0 per cent) than that of long-term shift (2.5 per cent). On an average, 41.0 per cent of farmers shift to off-farm works between 1-4 months and 4-8 months, while the remaining 11.5 per cent were displaced from 8 to 12 months annum^{-1}. In case of liability, a maximum of 84.8 per cent of the land was maintained by the family members of the farmer, 5.4 per cent by the friends/relatives and 3.3 per cent were leased.

Crop failure was caused by high rainfall, which caused stagnation of water and turns paddy to soil, which reduce crop production by one-third. During migration, responsibilities were transferred into the hands of the respective loved ones. Significantly, this acts as an additional burden, while they do not receive any moral or financial credit for the work they do. Often the type of migration of farmers depended on the adaptation strategies followed and the monsoon days.These findings have also been supported by a study conducted in Punjab. It reveals that, due to the negative impact of climate change, in Punjab, almost 38.54 per cent of marginal farmers and 43.4 per cent of small landholding farmers took a shift from farm to non-farm activity. The marginal farmers were highly de-peasantized (the act of farmers shifting from agricultural work to non-agricultural activities for the sake of survival is termed as de-peasantization) and it was due to the non-profitability and failure to enhance their livelihood (Singh and Bogal, 2014).

Region-specific adaptation behaviour

The logistic regression model (Table 5) was performed to ascertain the effects of region with limited irrigation facility and its adaptation behaviour (dichotomous variable, 1 = Yes, region with limited irrigation facility, 0 = otherwise). This model was employed to identify the influential factors in the model of adaptation strategies of rural farmers with limited irrigation facilities.

The results indicated that, together, the predictors accounted for a significant amount of variance in adaptation strategies of rural farmers with limited irrigation facilities, likelihood ratio $\div^2_{(17)} = 488.71, p< .001$ and correctly classified 93.5 per cent of cases. Adaptation strategies of farmers largely corresponded to the factors such as land reclamation through adaptation strategies (b = 3.755, SE = 0.521, $p<$ 0.001), risk mitigation measures (b = 0.446, SE = 0.161, $p<$ 0.001), time to reclaim uncultivable land (b = 6.094, SE = 1.428, $p<$ 0.001) and technical barriers (b = 1.153, SE = 0.411, $p<$ 0.001). Also, the variable, number of days shifted from farming was significant at 5 per cent level. Despite the positive integers, the reclamation of uncultivable land was 2.3 times higher compared to the perception of land reclamation. Besides, there was a negative correlation between loss of income (b = 3.755, SE = 0.521, p <0.001), loss of time (b = 3.755, SE = 0.521, p <0.001), and satisfaction level (b = 3.755, SE =). 0.521, p <0.001), and limited irrigated area, whereas a value below 1 (odds ratio) implied reduction in the probability of occurrence of an event. In particular, a part-specific adaptation of mitigation strategies does not reduce the level of revenue, time and strategy satisfaction. Similarly, adaptation type (b = -2.448, SE = 0.959, $p<$ 0.05), reason for change of job (b = -0.574, SE = 0.124, $p<$ 0.05), problems encountering strategies (b = -4.671, SE = 1.856, $p<$ 0.05) and institutional barriers (b = -0.842, SE = 0.342, $p<$ 0.05) were negatively correlated with the area of low irrigation facilities. In addition, the variable, risk associated in farming also had a negative relation with the limited irrigation area with an odds ratio of 0.81.

Similarly, a study analysed the perception of dry land farmers regarding changing climate, impacts and adaptation strategies followed in Tamil Nadu. It signifies that there was a declined trend in summer months and increasing summer temperature, also there was a declined trend in southwest monsoon and rainfall over the years. The aged or experienced farmers were more hopeful to manage the Climate change than the younger aspirants and the remaining were more dependent on livestock for income generation purposes. As an adaption measure farmer mostly, practiced inter/mixed cropping and manipulation of sowing date technique as a water conservation strategy (Varadan and Pramod Kumar, 2014).

The replications of area wise adaptation and mitigation strategies

The estimates of multinomial logit model for village wise adaptation and mitigation behaviour of small and marginal farmers were given in Table 6. The model included the adaptive behaviours for four selective village panchayats *viz.*, Veppanuthu, Ayyanarkulam, Villur and S. P. Natham, respectively. Moreover, the study fields were classified as (i). area with (Veppanuthu and Ayyanarkulam) and, (ii) without irrigation facilities (Villur and S. P. Natham). The robustness of the model was proved at one per cent significance through likelihood ratios, while the model fit were shown with the outcome of McFadden test.

Area with irrigation sources

In terms of adaptation behaviour, the irrigated approach to mitigation was inversely related to each other. In specific, the factors of rationalisation and problems encountered during adoption were negatively related for Veppanuthu, whereas, in contrast, the said variables were positively associated with Ayyanarkulam, respectively. This was due to the educational and seasonal information resources available among the farmers of Ayyanarkulampanchay at. Furthermore, the results revealed that farmers in the Veppanuthupanchayathad lost their income between 320 -640.5 USD annum^{-1}ha^{-1} due to climate change. The incidence of dreadful income loss was due to the slopping part of the land and the happenings of extreme floods during the monsoon season. With respect to the strategies, increasing off-farm income, irrigation and mulching was significant. Besides, the rationality of strategy selection was based on the periodic intervention of extension activity but the farmers were not much satisfied with it. Both the small and marginal farmers of Veppanuthu faced economic problems when dealing with strategies.

The model of Ayyanarkulam revealed that the practice of conventional farming by increasing pesticides, changing crop varieties, migrating and practising crop rotation dwelled into a low level of standards along with an annual income loss of 240 USD to 320 USD, respectively. The income loss and problems met were negatively related at a 5 per cent level significance. The most important and promising finding of the study was that two-thirds of the residents of Ayyanarkulam were government servants and, therefore, agriculture was the secondary income. Nevertheless, agriculture for this panchayat have been considered as a mark of status hence, the loss of secondary income would not be as much of an impact as expected.

Area lacking irrigation facility

The results of the model cast a new light on the areas lacking irrigation facilities. The rationale behind the choices of strategies was negatively related to Villur and positive with S.P.Natham panchayats, correspondingly. On the other hand, the income lost was negatively related to both the panchayats simultaneously. This was plausible because these panchayat farmers have frozen their investment years before; others have started withdrawing from the recent or previous investment. Especially, farmers preferred to migrate rather than continue farming and their (small and marginal) lands remain barren.

Contrarily, the problems came across by the farmers while adapting were positively connected to the Villur and negatively to the S. P. Natham panchayats at 1 per cent level of significance. A further novel finding was the farmers of S. P. Nathampanchayat have an understanding that investing in deep wells would bring in saltwater, while 2 farmers from the same zone had spent up to twelve lakh rupees on digging of wells and were now trapped in a debt trap. As the field yields, zero or lesser returns, the withdrawal of investment from agriculture was twice as fast as the investment made in the areas with minimum irrigation facilities. In particular, the rate of farm-to-off-farm migration was increasing due to unavailability of credit and technical barriers.

Anticipated movement from resilience to adaptation

The growing need for adaptation and mitigation strategies depends on the impact of climate change on small and marginal farmers. The movement of small and marginalized people was picturized (Fig.1) with the support of cost-benefit analysis in two categories *viz.*,

i) where they are (when adaptation is not possible) and

ii) where they should be (when full adaptation is possible).

Concept and definition

Farmers have to pay for pre-farming farm inputs and household expenses. But nowadays farmers have a part of the investment to meet the adaptation and mitigation strategies to deal with the climate impacts, putting an additional burden on the production process to move forward. Understanding the necessity of limiting costs in farming this study adopted the concept of cost-benefit analysis. According to researchers, the cost-benefit analysis in farming was defined as a theoretical prediction of future production with the current adoption of adaptation strategies.

Assumptions

The theoretical framework has been based on the following assumptions.

i) The cost incurred for inputs, household expense and adaptation strategies remain linear for a short span, and

ii) Household members responded to the questions in a fair manner, while neither to influence the study nor the other chosen household head.

Graphical Illustration

a) When full adaption is possible.

a) When full adaption is not possible.

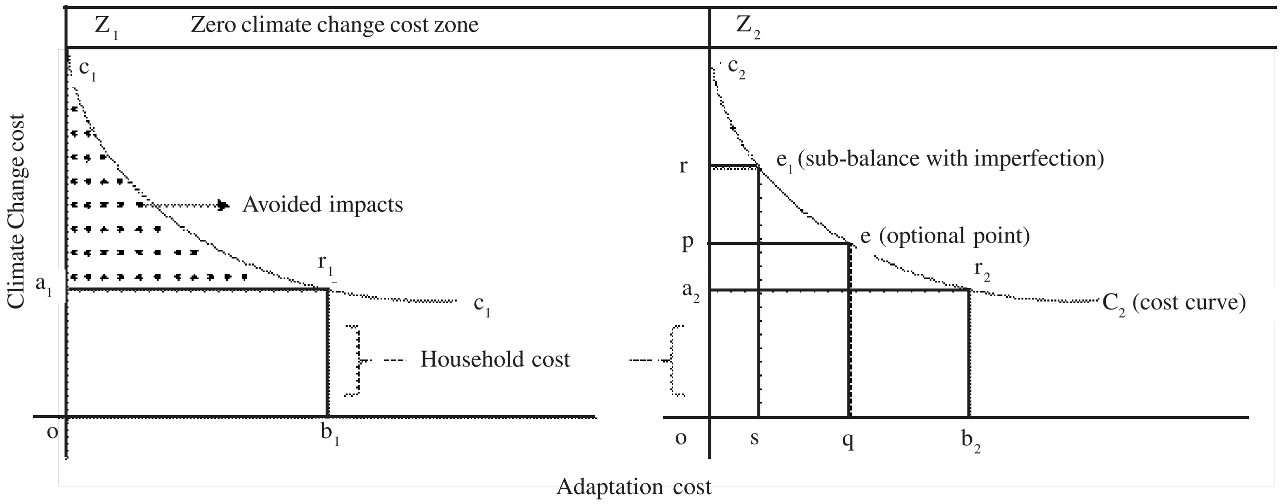

Fig. 1 Shifty graph (from 'where we meant to be' to 'where the farmers are now')

In Fig.1

$C_1 C_2$	- represents the cost curve (Average cost incurred by farmers in terms of climate change)
a_1 $b_1$and a_2 b_2	- indicates the unavoidable residual cost
$r_1 r_2$	- denotes the minimal residual cost or the optimal point of average other costs
p r	- symbolizes the climate change cost
s q	- signifies the adaptation cost incurred by the small and marginal farmers
*e*ande_1	- represents the optimal balance point and sub-balance with imperfection
$z_1 z_2$	- stands for the region of zero climate change cost zone

Theoretical explanation

There was always an economic cost to protecting open land. Also, economic cost includes both implicit and explicit costs. It was clear from Table 3 that the non-productive use of land during the adoption period forces farmers to remain idle or opt for off-farm work. This type of disuse of land was not kept accounted for elsewhere. This type of unavoidable and unaccounted cost was termed as an 'implicit cost'.When full adaptation was possible, farmers spend less on climate impacts. As indicated by the dotted lines, the costs of climate change impacts were reduced as spending on adaptation strategies increases. This includes household or residual expenditure, *i.e.*, 'oa_1b_1' at equilibrium point r_1. When full adaptation was not possible, the farmer pays the amount 'ra_2e_1' of the price for climate impacts, including the household cost 'oa_2b_2' in equilibrium r_2. Similarly, if the farmer use indigenous knowledge, it result in a small amount and find the fixed adaptation cost + minimal climate change cost + residual cost ($pa_2e + oa_2b_2$). One might suspect that the investment spent on adaptation was futile. It was clear from Table 1 that the production of 98.8 per cent of farmers who adopted adaptive strategies gave 16.6 per cent additional yield. Hence, it was a win-win for farmers. Besides, Figure1 depicts that if adaptation cost changes from 'os' to 'oq', there would be lower climate change costs from 'or' to 'op' (optimal point). This would ultimately disrupt the investment made by farmers, thereby causing a short-term conversion effect from 'investment in farm operations' to 'investment in climate change mitigation'. Also, it would bring the farmer's equilibrium from 'e_1' (deficient sub-equilibrium) to 'e' (optimal point). Additionally, the continuum of adaptation costs would wither away at a constant rate and resulted in a 'z_1z_2' zero climate change cost zone. This kind of out-of-pocket payment that was actually made was termed an 'explicit cost'.

The productivity growth of a country was the main driver of economic growth. Such productivity provides a less productive environment for economies due to climate change. Thus, the chain reaction effect of climate change was that climate change => declining productivity => significantly declining labour productivity => declining economic growth => declining investment. Therefore, the need for adaptation and recovery strategies increased many times over. In the study field both the small and marginals have a weak coordination and less adaptive behaviour. There was a need for robust shift from the present circumstances to the developed state. For the region lacking irrigation facility, they not only have to incur climate related costs but also for other events. In particular, the farmers with irrigated and non-irrigated lands met up with problems like animal attacks, aging, technological inclusion, livestock disease and irrigation expense/purchasing water. The farmers with non-irrigated lands encounter animal attacks at the time of harvesting. Hence, they were responsible for both the climate change cost and animal attacks prevention cost. Especially, to preserve the crops from attacks they adopted two types of methods (i) reduction of the crop gaps while planting (inexpensive and ineffective), and (ii) securing lands with electric cables (expensive and effective). Therefore, farmers who spend other than adaptation end up with equal level of pay for other extreme events. Aging served as an important factor in both the areas, even though the farmers with sumptuous wealth were not prepared to adopt. Because lacking man-power and elderly age served as a vital restricting factor. Climate change not only hindered production but also the livestock. Therefore, without adjusting for climate change in the first place, none of the effects of its extensions here can be reversed. Thus, the onus was on the central government in general and the state government in particular to create understanding among the farmers about the need and necessity of the strategies. Therefore, adaptation-oriented workshops and inclusive programs to enrich the knowledge of smallholder farmers is the need of the hour. Moreover, the most common strategies adapted by the farmers were increasing pesticides, changing crop varieties and practicing crop rotation.

In particular, in the irrigated areas, the late samba varieties such as IR 20 and White Ponni were replaced with Akshaya rice variety. On the other hand, the rainfed area farmers reduced the sowing gap for crops like sorghum, bajra, green pea and field bean for the elimination of animal intrusion into the field. In economic view point the mentioned strategies were effective and less expensive. In the irrigated area, the changed crop varieties from IR 20 to Akshaya variety costed the same amount with seven tonnes of additional production. Similarly, the practice of crop rotation and reduced crop gap eliminated the crop loss due to animal attack. Therefore, in general, India and Tamil Nadu

Table 1. Choice and rationality of adaptation and mitigation strategies

	Variables and their attributes	Frequency	Per cent
Speculation on external pressure received from fellow farmers	Conventional method	57	11.9
	Doesn't face any kind of external pressure	423	88.1
Miligation strategies adapted to tackle climate change	Increase pesticies, changing crop varieties, practicing crop rotation	100	20.8
	Increase off-farm income, increasing irrigation, increase mulching	46	9.6
	Changing harvest time and practicing crop diversification	88	18.3
	Agro forestry, salinity tolerant crops and soil conservations	57	11.9
	Integrated farming system and changing the planting time	40	8.3
	Use of drought tolerant crops, changing planting structure and cover cropping	16	3.3
	Living fences, multipurpose trees and zero tillage	54	11.3
	Taking out insurance and focuses on weather forecast	34	7.1
	Application of soil protection technology	45	9.4
Rationale behind the choice of adaptation and mitigation strategies	Educational level	11	2.3
	Agricultural experience	77	16.0
	Arable land size	86	17.9
	Size of livestock/sheep herd	65	13.5
	Farm and non-farm income	40	8.3
	Credit access	19	4.0
	Based on climate information	48	10.0
	Frequency of extension contact	42	8.8
	Strategies effectiveness	92	19.2
Pre-adaptation production	Below 25 bags per hectare	480	100
Post-adaptation production	Below 25 bags per hectare	6	1.3
	25 to 30 bags per hectare	474	98.8
Level of satisfaction derived from the strategy	Far below standards	105	21.9
	Below standards	161	33.5
	Meets standards	180	37.5
	Far above standards	34	7.1

Source: Estimated from field survey data
Sample Households (N) = 480

Table 2. Structural barriers faced by small and marginal farmers

Variables and their attributes		Frequency	Per cent
Problems encountered when dealing with strategies	Technological barriers	130	27.1
	Economic barriers	274	57.1
	Institutional barriers	76	15.8
Technological barriers	Absence of drought tolerant crops	78	16.3
	Lack of location-specific machineries	23	4.8
	Less research on climate change and adaptation in various agricultural dimensions	9	1.9
	Less development of irrigation and water capacity infrastructure in rainfed areas	20	4.2
Economic barriers	High adaptation cost, Lack of financial facilities and Expensive inputs	197	41.04
	Poor storage facilities and Retention of small and fragmented land	77	16.04
Institutional barriers	Poor coordination and disability	17	3.5
	Unequal distribution of responsibility for adaptation	13	2.7
	They do not care enough to change	46	9.6

Source: Estimated from field survey data
Sample Households (N) = 480

Table 3. Risks and risk coping mechanisms in farming

Variables and their attributes		Frequency	Per cent
Risk associated in farming	Production risk	81	16.9
	Price or market risk	49	10.2
	Financial risk	47	9.8
	Institutional risk	65	13.5
	Human or personal risk	40	8.3
	Uncertain natural growth processes of crops and livestock	19	4.0
	Production, Price and Financial risk	179	37.3
Risk coping mechanisms	Precautionary savings, Credit reserves and Accumulation of liquid cash	120	25
	Semi-liquid assets, Off-farm job and Economic activity not related to farming	135	28.1
	Crop insurance, Maintaining financial reserves and Animal insurance	103	21.5
	Joining a producer group, Cooperation with supplier and receiver	22	4.6
	Farm production diversification, Land Leasing contracts and Avoiding credit	100	20.8
Income lost due to climate variability	Rs. 7,887 – Rs. 13,160	27	5.6
	Rs. 13,161 – Rs. 19,758	143	29.8
	Rs. 19,759 – Rs. 26,354	104	21.7
	Rs. 26,355 – Rs. 52,733	147	30.6
	More than Rs. 52,734	59	12.3
Lost time for the mitigation strategy	Less than 6 months	327	68.1
	6 - 12 months	28	5.8
	1 - 2 years	125	26.0

Source: Estimated from field survey data
Sample Households (N) = 480

Table 4. De-peasantization behaviour of the small and marginal farmers

Variables and their attributes		Frequency	Per cent
De-peasantization activity	Yes, we shift for off-farm activities	449	93.5
	No, we don't	31	6.5
Reason for switching job	Rural poverty	60	12.5
	Unemployment	84	17.5
	Crop failure	150	31.3
	Food insecurity	99	20.6
	Lack of social security	39	8.1
	Drought	17	3.5
	Don't prefer job shifting	31	6.5
Type of migration	Short-term	437	91
	Long-term	12	2.5
	Don't prefer job shifting	31	6.5
Number of days shifted to work off-farm	Less than 1 – 4 months	196	40.8
	4 – 8 months	198	41.2
	8 – 12 months	55	11.5
	Doesn't make any shift	31	6.5
Responsible household member for the land (during migration)	Family member	407	84.8
	Friends/relatives	26	5.4
	Will be leased	16	3.3
	Doesn't participate in Off-farm jobs	31	6.5

Source: Estimated from field survey data
Sample Households (N) = 480

Table 5. Estimates of Binary Logistic Regression Model

Variables	Coefficient	Odds ratio	95% C. I.	
			Lower	Upper
Kind of adaptation	-2.448**(0.959)	0.086	0.013	0.567
Rationale behind the choice of adaptation and mitigation strategies	0.063(0.123)	1.065	0.837	1.356
Income lost due to climate variability	-2.218***(0.291)	0.109	0.062	0.192
Perception on reclamation of land through adaptation strategies	3.755***(0.521)	42.740	15.397	118.643
Type of strategy used to mitigate the unculturable land	-0.080(0.101)	0.923	0.758	1.124
Level of satisfaction derived from the strategy	-0.667***(0.258)	0.513	0.309	0.852
Lost time for the mitigation strategy	-0.994***(0.292)	0.370	0.209	0.656
Risk associated in farming	-0.213*(0.124)	0.808	0.634	1.030
Risk coping mechanisms	0.446***(0.161)	1.563	1.139	2.144
Reason for switching job	-0.574**(0.226)	0.563	0.361	0.877
Number of days shifted to work off-farm	0.828**(0.331)	2.290	1.196	4.382
Responsible household member for the land	0.826(0.589)	2.285	0.720	7.249
Time to bring uncultivable land back into production	6.094***(1.428)	443.061	26.961	7281.080
Problems encountered when dealing with strategies	-4.671**(1.856)	0.009	0.000	0.356
Technological barriers	1.153***(0.411)	3.169	1.415	7.093
Institutional barriers	-0.842**(0.342)	0.431	0.220	0.842
Constant	10.850***(3.998)	51553.027		
Log likelihood	159.734			
$\div^2_{(17)}$	488.712***			
Cox and Snell R^2	0.639			
Overall % correct	93.5			
Observations	480			

Source : Author's estimation based on field survey data, N = 480
Note : ***, ** and * indicates 1, 5 and 10 % level of significance, Figures in the parenthesis represents the SE values

Table 6. Estimates of Multinomial Logistic Regression Model

Exogenous variables	Area with irrigation		Area lacking irrigation	
	Veppanuthu	Ayyanarkulam	Villur	S. P. Natham
Kind of adaptation	0.005(0.446)	0.910**(0.437)	-0.973*(0.502)	-0.066(0.466)
Rationale behind the choice of adaptation and mitigation strategies	19.907***(0.649)	-1.796**(0.760)	-19.286***(0.705)	18.154*(0.730)
Income lost due to climate variability	-1.718***(0.392)	1.174***(0.398)	-2.500***(0.711)	-1.880***(0.484)
Type of strategy used to mitigate the unculturable land	-2.168**(1.024)	2.261***(0.848)	0.435(0.630)	0.037(0.664)
Level of satisfaction derived from the strategy	-1.234***(0.469)	1.637***(0.475)	-1.263(0.988)	-1.556(1.185)
Problems encountered when dealing with strategies	1.425***(0.358)	-0.891**(0.374)	1.823***(0.518)	-1.728***(0.616)
Constant	1.807**(0.819)	-2.025**(0.812)	2.145*(1.244)	4.823***(1.463)
Likelihood ratio statistics	343.259	337.704	258.719	236.640
Probability of likelihood ratio	0.000	0.000	0.000	0.000
McFadden Test (Goodness of fit)	0.309	0.269	0.334	0.381

Source : Author's estimation based on field survey data, N = 480
Note : ***, ** and * indicates 1, 5 and 10 % level of significance, Figures in the parenthesis represents the SE values

need to improve administrative practices and issues on multiple fronts for farmer's advancement. Provision of crop diversification benefits, training on the most essential 'adaptation strategy', providing material wealth, social content, creating livelihood opportunities could lead to a significant increase in labour participation thereby reduces de-peasantization. Moreover, the benefit of insurance was that infiltration into the most remote and economically backward areas, without being as common as villages, could lead to healthy consequences thereby supports the farmers to purchase expensive inputs and fulfil the financial constraints. In addition, insurance ideas were needed to link poor farmers into the value chain. Also, there was a strong need to identify and strengthen deficiencies and poor coordination in technical protocols, institutions and local techniques.

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